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Investigation of N-N* Electromagnetic Form Factors within a Front-Form CQM

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Abstract

The helicity amplitudes for the transitions $N - S_{11}$ and $N - S_{31}$ are presented. The amplitudes have been obtained within our front-form CQM model, based on hadron eigenstates of a relativistic mass operator and CQ current with Dirac and Pauli form factors.

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Hadron electromagnetic (em) form factors have been recently investigated within the front-form constituent quark (CQ) model of [1] for space-like values of the four-momentum transfer. The main features of the model are: i) the use of hadron eigenfunctions of a relativistic mass operator, that includes an effective $q-q$ interaction and reproduces the hadron spectra for a large set of quantum numbers [2]; ii) the use of a one-body em current operator containing phenomenological Dirac and Pauli form factors for CQ's, which are determined by the request of reproducing the existing experimental data for the pion and nucleon elastic form factors (cf. [1]). Such a model has been already applied for obtaining a parameter-free prediction of the em form factors for the transitions to $N^*(1440)$ and $\Delta(1232)$, including the possible effects due to the D-wave components in the Δ wave function, [1].

In this contribution, we will present an analysis of transition form factors for $N \rightarrow S_{11}(1535)$, $N \rightarrow S_{11}(1650)$ and $N \rightarrow S_{31}(1620)$.

The current for negative-parity transition with $J_f = 1/2$ is given in terms of Dirac ($F_1^{f\tau}$) and Pauli-like ($F_2^{f\tau}$) form factors by (cf. [3])

$$\bar{\Psi}_f \; J^\mu \; \Psi_\tau = \bar{\Psi}_f \gamma^5 \left[\frac{p_f^\mu + p_i^\mu}{M_f - M_i} F_2^{f\tau} - \frac{M_f + M_i}{M_f - M_i} q^\mu F_1^{f\tau} + \gamma^\mu (F_1^{f\tau} + F_2^{f\tau}) \right] \Psi_\tau \tag{1}$$

where $\tau = p, n$. By using such a current, the helicities for negative-parity transition can be written as follows

$$\begin{aligned} S_{1/2}^\tau(Q^2) &= \zeta \; \sqrt{\tfrac{2\pi\alpha}{k^*}} \sqrt{\tfrac{Q^+}{2M_i M_f}} \sqrt{\tfrac{Q^+ Q^-}{4M_f}} \, \tfrac{M_f - M_i}{Q^2 \sqrt{2}} \left[F_1^{f\tau} - \tfrac{Q^2}{(M_f - M_i)^2} F_2^{f\tau} \right] \\ A_{1/2}^\tau(Q^2) &= -\zeta \; \sqrt{\tfrac{2\pi\alpha}{k^*}} \sqrt{\tfrac{Q^+}{2M_i M_f}} \left(F_1^{f\tau} + F_2^{f\tau} \right) \end{aligned} \tag{2}$$

where ζ is the sign of the πN decay amplitude, $k^* = (M_f^2 - M_i^2)/2M_f$, $Q^\pm = (M_f \pm M_i)^2 + Q^2$. The invariant form factors in Eq. (2) can be obtained within the front-form CQ model following standard procedures (see, e.g., [1]), namely approximating the plus component of the transition current, $\mathcal{I}^+$, in terms of the sum of one-body CQ currents, containing CQ Dirac and Pauli form factors. In particular

$$F_1^{f\tau} = -\frac{1}{2} Tr \left(\sigma_z \mathcal{I}^+(\tau) \right) \qquad F_2^{f\tau} = -\frac{M_f - M_i}{2Q} Tr \left(\sigma_x \mathcal{I}^+(\tau) \right). \tag{3}$$

where $\mathcal{I}^+_{\nu_f \nu_i}(\tau) = \bar{u}^f_{LF}(\nu_f) \sum_{j=1}^3 \; \left(e_j \gamma^+ f_1^j(Q^2) \; + \; i\kappa_j \frac{\sigma^{+\rho} q_\rho}{2m_j} f_2^j(Q^2) \right) u^\tau_{LF}(\nu_i)$.

In Figs. 1-5, our *parameter-free* evaluation of the helicity amplitudes, $A_{1/2}$ and $S_{1/2}$ are shown for $N \rightarrow S_{11}(1535)$, $S_{11}(1650)$ and $S_{31}(1620)$, respectively. In the case of $S_{31}(1620)$ the results for p and n coincides (as in the case of $P_{33}(1232)$), since only the isovector part of the CQ current is effective, given the isospin of the resonance.

The overall agreement between our predictions and the data is encouraging, though a most accurate set of data is necessary in order to reliably discriminate between different models. However, the sensitivity to relativistic effects for the P-wave resonances seems sizable.

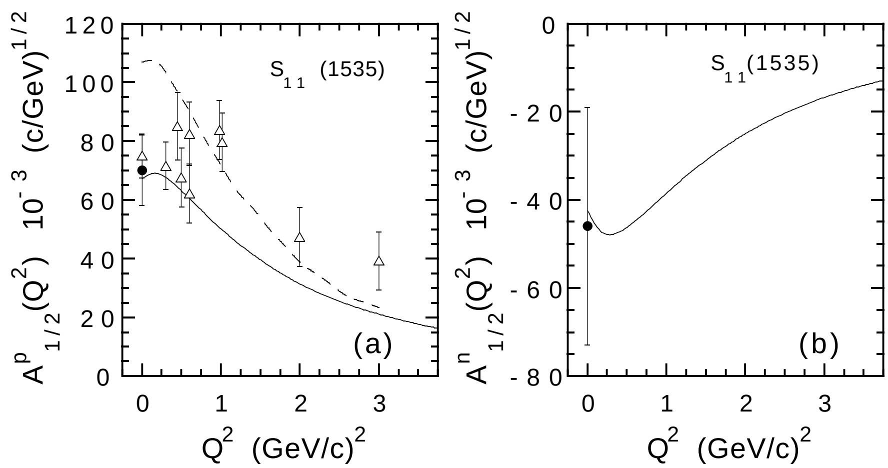

Figure 1. - (a) The transverse helicity $A_{1/2}$ for the transition $p \to S_{11}(1535)$ vs. Q^2. Solid line: $A_{1/2}$ from the hadron wave functions corresponding to the interaction of [2] and the nucleon em current with CQ form factors of [1]; dashed line: a non relativistic CQM calculation [4]. Solid dot: PDG '96 [5]; triangles: data analysis from [6]. - (b) The same as in Fig. 1(a), but for $n \to S_{11}(1535)$.

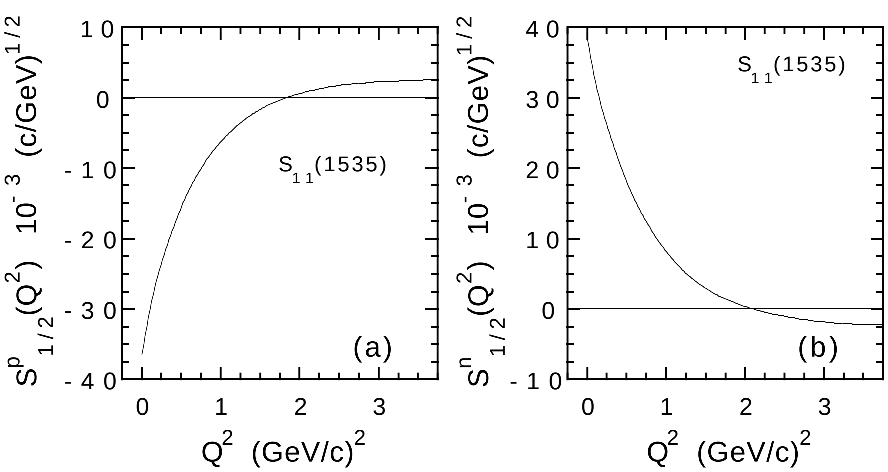

Figure 2. The same as in Fig. 1, but for the longitudinal helicity $S_{1/2}$.

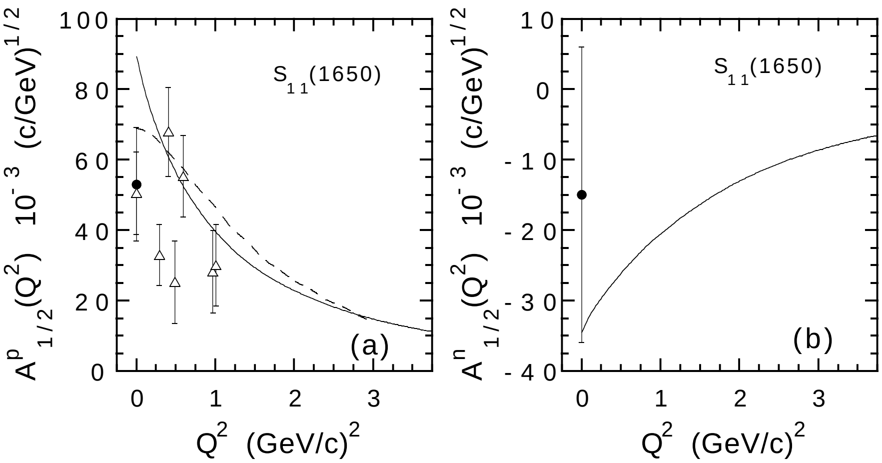

Figure 3. - (a) The transverse helicity $A_{1/2}$ for the transition $p \rightarrow S_{11}(1650)$ vs. Q^2. Solid line: $A_{1/2}$ from the hadron wave functions corresponding to the interaction of [2] and the nucleon em current with CQ form factors of [1]; dashed line: a non relativistic CQM calculation [4]. Solid dot: PDG '96 [5]; triangles: data analysis from [6]. - (b) The same as in Fig. 3(a), but for $n \rightarrow S_{11}(1650)$.

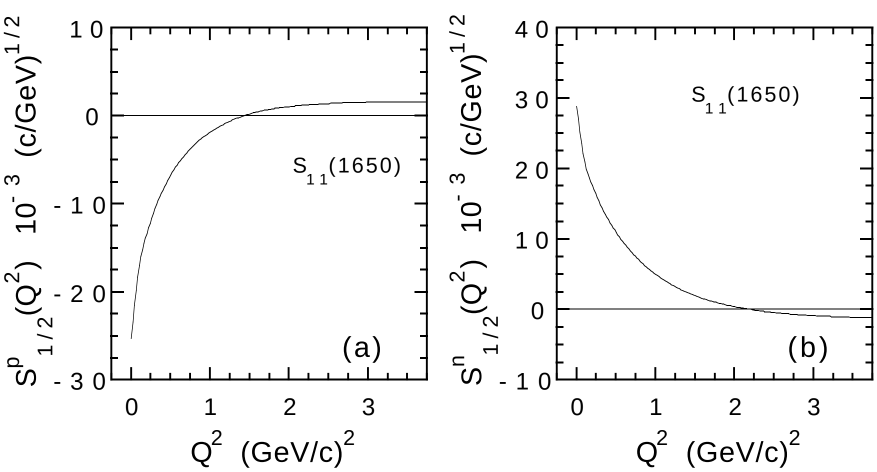

Figure 4. The same for Fig. 3, but for the longitudinal helicity $S_{1/2}$.

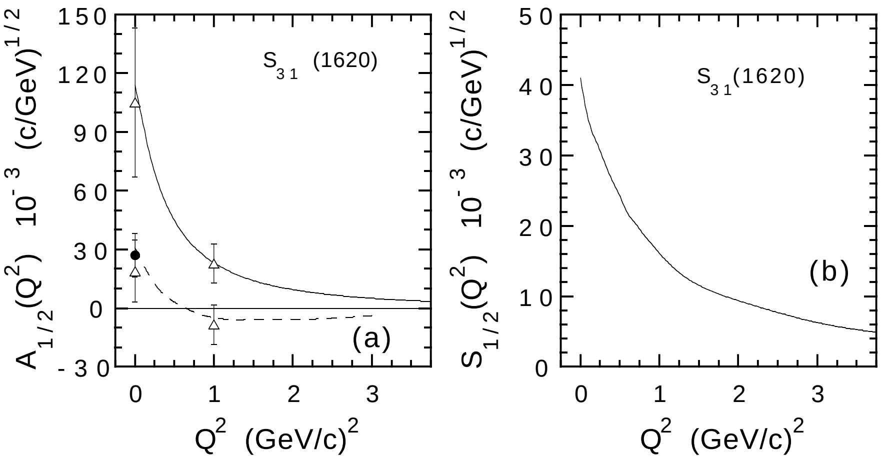

Figure 5. - (a) The transverse helicity $A_{1/2}$ for the transition $p \to S_{31}(1620)$ vs. Q^2. Solid line: $A_{1/2}$ from the hadron wave functions corresponding to the interaction of [2] and the nucleon em current with CQ form factors of [1]; dashed line: a non relativistic CQM calculation [4]. - (b) The same as in Fig. 5a, but for $S_{1/2}$.

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